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Fatigue Management for Aerospace Expeditionary Forces Deployment and Sustained Operations

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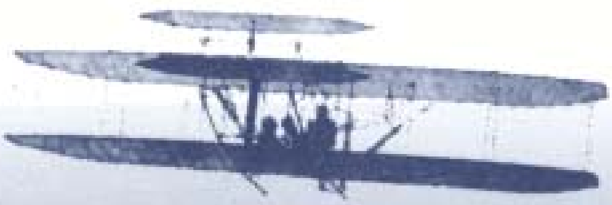
Air Command and Staff College
Wright Flyer Paper No. 12



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MAXWELL AIR FORCE BASE, ALABAMA

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Foreword

It is my great pleasure to present another of the *Wright Flyer Papers* series. In this series, Air Command and Staff College (ACSC) recognizes and publishes the "best of the best" student research projects from the prior academic year. The ACSC research program encourages our students to move beyond the school's core curriculum in their own professional development and in "advancing aerospace power." The series title reflects our desire to perpetuate the pioneering spirit embodied in earlier generations of airmen. Projects selected for publication combine solid research, innovative thought, and lucid presentation in exploring war at the operational level. With this broad perspective, the *Wright Flyer Papers* engage an eclectic range of doctrinal, technological, organizational, and operational questions. Some of these studies provide new solutions to familiar problems. Others encourage us to leave the familiar behind in pursuing new possibilities. By making these research studies available in the *Wright Flyer Papers*, ACSC hopes to encourage critical examination of the findings and to stimulate further research in these areas.

John T. Sheridan, Brig Gen (Sel), USAF
Commandant

Preface

Having flown in a single-seat cockpit more than 14 hours deploying to Southwest Asia, I am familiar with the negative effects of long duration flights as well as the impact transmeridian sorties have on an aircrew's circadian rhythm. Any attempt to make that experience less painful for the aviators climbing into their jets during future deployments deserves pursuit and further investigation. Unfortunately, a great deal of the information available for the operational aircrews is either underemphasized at best or totally ignored by the personnel that the data is intended to support, the aviators. Typically, fatigue and circadian rhythm disruption are assumed as "necessary evils" that aviators have no choice but to accept. Yet fatigue can be a significant factor in terms of performance degradation and must no longer be overlooked. I have amassed the most current research regarding fatigue and its associated countermeasures, and I strongly recommend both commanders and aircrews apply the information presented in this research paper if they are to continue to safely meet the challenges of an Expeditionary Aerospace Force.

I thank my research advisor for his guidance and constructive criticism. I thank the flight surgeons at Brooks Air Force Base, Texas, for their contributions of valuable background material as well as drafts for their upcoming revision to the *Flight Surgeon's Checklist*.

Abstract

Under the new Expeditionary Aerospace Force (EAF) concept, the US Air Force is capable of deploying and employing in 72 hours or less. Furthermore, the US mission frequently requires 24-hour activities to meet operational demands. Because of its commitment to project power with such a rapid fighting force, aviators on contingency operations will regularly face fatigue-related challenges inherent in sustained and continuous operations, as well as those from rapid, transmeridian travel. The purpose of this research paper is to extract all relevant materials pertaining to fatigue and aircrews in order to provide a plan for equipping Aerospace Expeditionary Forces (AEF) commanders and personnel with a historical perspective, critical information, and new technologies to enable effective fatigue management. This information was attained via an extensive literature search and review, primarily utilizing the Internet and the Air University Library.

Existing comprehensive scientific literature provides important physiological information about aviators that can be used to guide operations and policy. Many alertness management strategies aid aircrews and deployed personnel as well as help them to cope with the challenges of sleep loss and circadian disruption. Both pharmaceutical and nonpharmaceutical countermeasures are presented. Although valuable, the challenge is for the scientific information to make its way down from the books to the cockpit and be incorporated into flight/duty/rest regulatory considerations. Additionally, new means to combat fatigue can give AEF commanders insight into future benefits of fatigue research. Commanders, safety officers, and aviators are well advised to familiarize themselves with the causes of impaired alertness and countermeasures that can keep chronic fatigue from becoming a problem. Sufficient knowledge will make it easier to predict dangerous situations related to on-the-job sleepiness, recognize warning signs of excessive fatigue in aviation personnel, and take action to prevent fatigue related hazards in the air. This paper concludes with the

recommendation that the USAF AEF Battlelab develop a commander’s handbook as a reference tool for leaders to make better decisions concerning alertness management strategies and fatigue countermeasures.

PART IÄ

MethodologyÄ

Introduction

> *We will continue to hone and improve the EAF concept as we implement it, incorporating lessons learned from ongoing AEF deployments.*
>
> *—US Air Force Posture Statement 2000*

The Expeditionary Aerospace Force (EAF) will regularly face fatigue-related challenges inherent in sustained and continuous operations, as well as those from rapid, trans-meridian travel. Fortunately, there are new techniques that can blunt fatigue, especially for the first few days of intense activity required of the Aerospace Expeditionary Forces (AEF). Reduction of fatigue and circadian disruption will be extremely important to the success of AEF goals. The challenges of fatigue must be dealt with and planned for to maximize human performance and mission success. A historical analysis of the operations and aviation will provide the defense for pursuing an initiative that targets logistical management of fatigue prevention strategies through crew rest, sleep countermeasures, and other means as crucial as managing bullets and gasoline to increase the likelihood of mission success.

The United States Air Force (USAF) doctrine of an expeditionary aerospace force and a demand for an accelerated operations tempo increases the likelihood of around-the-clock operations in order to sustain its constant presence.[1] By flying at night—under greater stress—and in different time zones, fatigue has a greater opportunity to impact the mission. Factors such as exposure to cockpit noise and vibration, day-to-day stress, lengthy flights, irregular work schedules, circadian disruption, and inadequate amounts of sleep can compromise aviator performance by producing dangerous levels of fatigue. Although the initial effects of fatigue often go unnoticed, vigilance, judgment, situational awareness, and crew coordination all may suffer.

The methodology applied during this research consisted of a comprehensive review of available materials concerning sleep deprivation and fatigue countermeasures. The author pursued a detailed literature review via the Internet and the Air University Library, whereby the focus was on the most current information available. After a detailed

database was established, the information was consolidated into a coherent reference source in order to assist the USAF AEF Battlelab to develop a handbook for commanders to use for guidance during AEF deployments. This research paper begins by developing a fundamental understanding of the EAF concepts followed by an explanation of the basic physiology behind sleep, circadian rhythms, and fatigue. Once a baseline knowledge of the core mechanisms behind fatigue is established, current countermeasures—both pharmaceutical and nonpharmaceutical—are presented. Next, future alertness management strategies are discussed. Finally, recommendations are made for the Battlelab to develop its handbook.

There is a wealth of information regarding fatigue and alertness management strategies. By presenting the most current pharmaceutical and nonpharmaceutical strategies available, commanders can make better choices concerning ways to enhance personnel's transition to deployed locations and combat the inevitable fatigue associated with sustained and continuous operations. In order to improve the EAF concept's effectiveness, the *US Air Force Posture Statement 2000* asserts that servicemen must incorporate the lessons learned from AEFs currently deployed. This paper intends to assist in the learning process by showing what can be done to counter fatigue.

Notes

1. Carol S. Ramsey and Suzanne E. McGlohn, "Zolpidem as a Fatigue Countermeasure," *Aviation, Space, and Environmental Medicine*, October 1997, 926–31.

PART II

Background: Historical Perspective

Aerospace Expeditionary Forces Concepts

EAF organizationally links forces in geographically separated units into standing air expeditionary forces. These forces would deploy from Air Force installations and be ready to fight or deliver humanitarian supplies on very short notice.

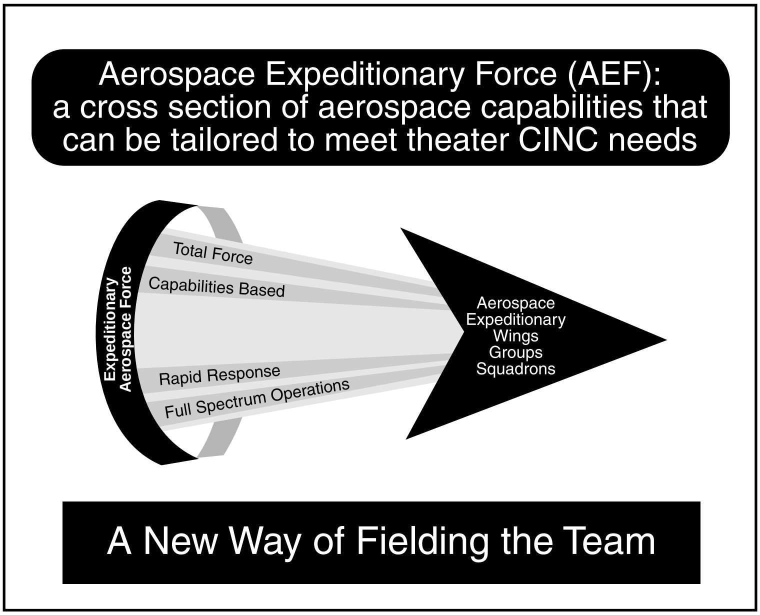
—Expeditionary Aerospace Force Press Briefing
4 August 1998

The US national security strategy explicitly states that the military must maintain our overseas presence to promote regional security. The ability to project power globally is "essential for providing options for responding to potential crises and conflicts, even when we do not have any permanent presence or a limited infrastructure in a region."[1] The EAF concept answers this country's need for a rapid, deployable force to project our nation's will and protect its interests. The concept also addresses the Air Force vision to organize, train, equip, and sustain its Total Force through enhanced sustainability, readiness and responsiveness, and through fostering an expeditionary warrior mindset.[2] The EAF structure can be summarized in four statements.[3] The rotational structure centers around 10 AEFs—employed two at a time for 90 days over a 15-month cycle. Additional manpower is made available to support each EAF component. The deploying units will be lighter and leaner—capable of deploying in 72 hours or less. The deployment forces must be organized and trained to meet the requirements of the contingency operation they will perform.

Figure 1 describes the AEF format by highlighting the key components necessary to sustain an EAF. Some of the issues confronted by a force that is capable and committed to putting bombs on target anywhere in the world in 72 hours or less is the disruption of circadian rhythms, operations tempo-induced fatigue, and the potential ill effects these stressors place upon aviators.

Fatigue and Aviation Safety Relationship

With a basic knowledge of the EAF concept and the fact that AEFs might face difficulties adjusting to their deployed



Source: Headquarters USAF/XOPE, EAF Implementation Division, *Aerospace Expeditionary Forces*, 1 October 1999.

Figure 1. What Are AEFs?

environment, the impact fatigue has on safety can now be scrutinized; and the potential danger areas for AEFs can be established.

Mishap Rates. Maintaining safe aviation operations is a complex task. For the foreseeable future, aircrews remain essential to safe, efficient, and reliable aviation activities. Therefore, the importance of addressing human-related error—which accounts for approximately 70 percent of aviation accidents—remains critical to maintaining and improving safety.[4] Fatigue generated by operational requirements can degrade human performance capability and reduce the safety margin. Estimates suggest that 75 percent of night workers experience sleepiness on every night shift; and for 20 percent of them, sleepiness is so severe that they actually fall asleep.[5] Approximately one of five reports to the National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) mention

fatigue-related factors.[6] Between 1974 and 1992, the USAF Safety Agency attributed 25 percent of night tactical fighter class A mishaps to fatigue. Mishaps are categorized into five classes: A, B, C, D, and E. Class A is the most severe. The Naval Safety Center attributed 12.2 percent of its class A mishaps between 1977 and 1990 to fatigue.[7] The Presidential Commission on the Space Shuttle Challenger Accident identified sleep loss as at least contributory to senior managers' poor decision making regarding launch.[8] It is apparent from the historical data presented that fatigue can have a negative impact for AEF operations if it is not correctly managed.

Causal versus Fatigue-related Factors. Author John A. Caldwell claims that many of the human errors accounting for more than one-half of all aviation accidents are probably the direct result of fatigue-related pilot inattentiveness and failures to respond to critical information in the cockpit.[9] Decreased performance related to sleep loss and circadian disruption has been implicated in some major disasters, such as the Exxon *Valdez*, Three-Mile-Island, and Bhopal accidents.[10] However, fatigue frequently is not cited as a causal factor in air carrier accidents despite evidence pointing to its role in mishaps. Examples of mishap-related "behavioral factors" listed in the ASRS include "motivational and attitudinal problems, complacency, distraction, sensory illusions, and resource utilization inadequacies," all of which can result from aircrew sleepiness and fatigue.[11] However, the first time that the National Transportation Safety Board (NTSB) cited fatigue as probable cause in an aviation accident was after the DC-8 crash at Guatánamo Bay in 1993.[12]

Physiological Aspects of Sleep

Modern sleep research began in the mid-1950s with the discovery of two distinct states of sleep. Over the past 45 years, there has been extensive scientific research on sleep, sleepiness, circadian rhythms, and the effects of these factors on waking alertness and performance.[13] Following is a brief overview of some of the relevant scientific information regarding human sleep, fatigue, and circadian rhythms.

Rapid Eye Movement versus Nonrapid Eye Movement

Historically, sleep has been viewed as a condition when the human organism is turned off. Scientific findings have clearly established that sleep is a “complex, active physiological state that is vital to human survival.”[14] Contrary to popular belief, sleep is not a homogeneous state.[15] Instead, sleep is composed of two distinct phases: nonrapid eye movement (NREM) and rapid eye movement (REM) sleep. These two sleep states are significantly different from each other.

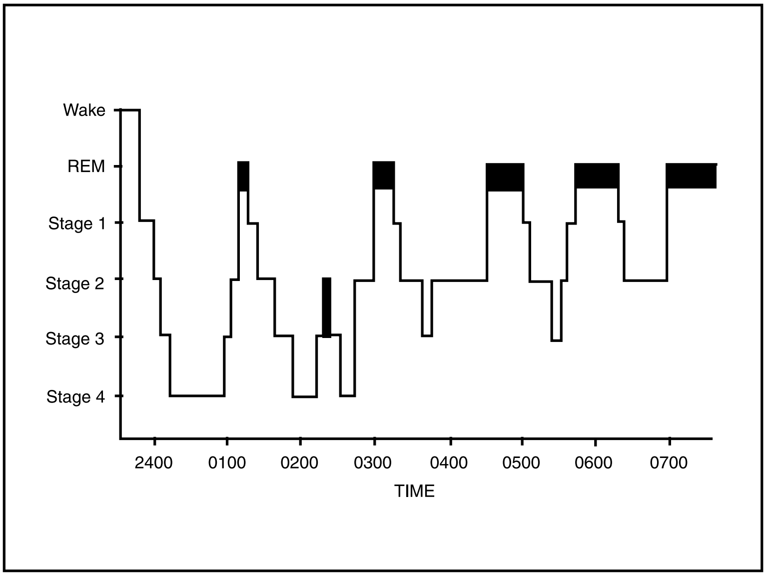
To begin with, NASA studies revealed that NREM sleep is divided into four stages, with the deepest sleep occurring during stages three and four. There is usually very little mental activity during these stages. During NREM sleep, physiological and mental activities decelerate (e.g., heart rate and breathing rate slow and become regular). If awakened during this deep sleep, an individual may take some time to wake up and then continue to feel groggy, sleepy, and perhaps disoriented for 10 to 15 minutes. This phenomenon is called sleep inertia.[16]

Conversely, REM sleep is associated with an extremely active brain that is dreaming and with bursts of rapid eye movements (probably following the activity of the dream). During REM sleep the major motor muscles of the body are paralyzed. If awakened during REM sleep, individuals can often provide detailed reports of their dreams.[17]

Sleep Cycle

Over the course of a typical night, NREM and REM sleep occur in a repetitive 90-minute cycle, with about 60 minutes of NREM sleep followed by about 30 minutes of REM sleep. Figure 2 shows this cyclical pattern.

From the histogram it is important to make note that most deep sleep (i.e., NREM stages three and four) occurs in the first third of the night, and REM periods are shorter early in the night and then become longer and occur more regularly later in the sleep period. Overall about 25 percent of sleep time is spent in REM sleep, and about 50 percent is spent in NREM stage two.[18]



Source: M. R. Rosekind et al., NASA Technical Memorandum 1999-208780, subject: Crew Factors in Flight Operations X: Alertness Management in Flight Operations, Moffett Field, Calif., Ames Research Center, 1999.

Figure 2. Histogram of Normal Sleep

Circadian Rhythms

Over evolutionary time, the daily cycles in the physical environment (produced by the earth's rotation) have become hard-wired into our neuronal circuitry in the form of a biological clock in the "suprachiasmatic nucleus of the hypothalamus."[19] Circadian rhythms govern sleep or wakefulness, motor activity, hormonal processes, body temperature, performance, and many other factors.[20] The circadian (circa = about; dies = day) enforces an approximately 25-hour cycle in many functions. Unless timing information is received from the environment, the human circadian clock tends to run slow to account for this 25-hour cycle. The specific environmental time cues that synchronize it to a 24-hour day are known by the German term zeitgebers, meaning time-givers. Currently two types of zeitgebers have been identified: exposure to bright light and social factors.[21] Moving to a new light or dark schedule

(e.g., night work or time zone change) can create internal and external desynchronization.[22]

Scientific studies have revealed that—based upon circadian factors—there are two periods of maximal sleepiness during a normal 24-hour day. One occurs at night roughly between 0300 and 0500, with many functions demonstrating reduced levels from 0000 to 0600.[23] The other occurs midday roughly between 1500 and 1700. M. R. Rosekind and associates concluded that this afternoon increase in sleepiness occurs whether a meal has been eaten or not, though the meal may aggravate the underlying sleepiness.[24]

Effects of Sleep Debt

Sleep loss is common and can be acute or cumulative. In an acute situation, sleep loss can occur either totally or as a partial loss. Total sleep loss involves a completely missed sleep opportunity and continuous wakefulness for about 24 hours or longer. Partial sleep loss occurs when sleep is obtained within a 24-hour period but in an amount that is reduced from the physiologically required amount or habitual total.[25] Sleep loss can also accumulate over time into what is often referred to as "sleep debt." Sleep loss—whether acute or cumulative—results in significantly degraded performance, alertness, and mood.

On average most humans physiologically require about eight hours of sleep per night.[26] However, individual requirements vary, so long as the required amount equates to "the amount of sleep necessary to achieve full alertness and an effortless level of functioning during waking hours."[27] Individual sleep needs vary, although most adults require about eight hours as mentioned above. Some people need six hours, but others require 10 hours to feel wide-awake and to function at their peak level during wakefulness.[28] Unfortunately, as the data will illustrate later, individual efforts to assess their true level of sleepiness can sometimes be grossly inaccurate. An individual who requires eight hours of sleep and obtains only six hours on a particular night is essentially sleep deprived by two hours. If that individual sleeps only six hours each

night over four nights, then the two hours of sleep loss per night would accumulate into an eight-hour sleep debt.[29]

Estimates suggest that in the United States today, many adults obtain one to 1.5 hours less sleep per night than they actually need.[30] During a regular workweek this would translate into the accumulation of a five to seven and one-half hours of sleep debt going into the weekend—hence, the common phenomenon of sleeping late on weekends to compensate for the sleep debt accumulated during the week. Sleep loss also can result in some extension of the usual sleep duration. However, this extension is much less than would be required to "make up" the lost hours of sleep. Both an increased amount of deep sleep and increased sleep duration can indicate a sleep debt.[31] After sleep loss, recovery is not accomplished through an hour-for-hour restitution. Rather, recovery is accomplished through an increase in deep sleep (NREM slow-wave sleep) starting on the first night of regular sleep. Typically, two nights of recovery sleep are needed to return to a normal baseline of waking performance and alertness.[32]

Physiological Aspects of Fatigue

The term *fatigue* has been used to describe many different experiences: sleepiness, physical tiredness, inability to focus mentally, and others. However, flying fatigue is defined as "a decrease in skilled performance related to duration or repetitive use of that skill, aggravated by physical, physiological and psychic stress."[33] Table 1 illustrates common signs and symptoms of fatigue.

Table 1-

Fatigue Signs and Symptoms-

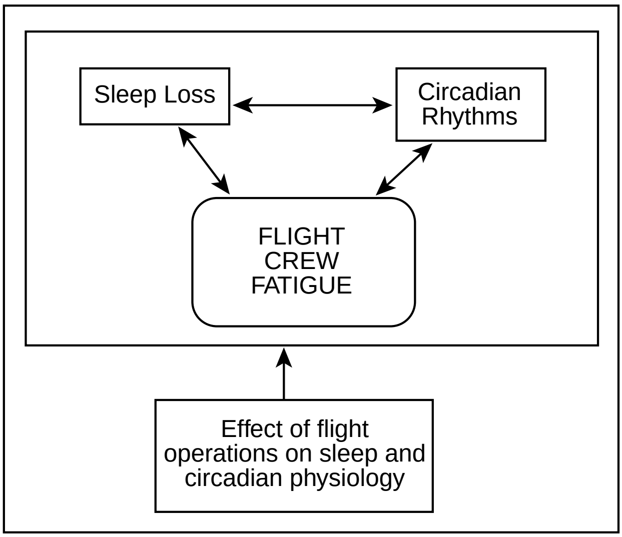
Forgetful	Slowed Reaction Time
Poor Decisions	Apathetic
Fixated	Lethargic
Reduced Vigilance	Bad Mood
Poor Communication	Nodding Off

Source: M. R. Rosekind et al., "Managing Fatigue in Operational Settings I: Physiological Considerations and Countermeasures," *Behavioral Medicine* 21, 1996.

Caldwell also described other indicators of insufficient sleep. They include the following difficulties:

- awakening without the aid of an alarm clock;
- repeatedly pressing the snooze button when the alarm sounds;
- feeling that a nap during the day is necessary to alleviate sleepiness;
- consistently looking forward to weekends or other times for the purpose of "catching up on sleep"; and
- frequently experiencing an inability to stay awake in meetings, while watching television, or during other sedentary activities.[34]

The effects of fatigue that concern the operational community—specifically those that affect crewmember alertness and performance—stem primarily from sleep loss, circadian rhythm disruption, and the interaction of the two.[35] Figure 3 shows the link between the variables that result in fatigue.



Source: M. R. Rosekind et al., NASA Technical Memorandum 1999-208780, subject: Crew Factors in Flight Operations X: Alertness Management in Flight Operations, Moffett Field, Calif., Ames Research Center, 1999.

Figure 3. Causes of Fatigue

Effects on Performance

Unfortunately, individual aviators and their commanders often underestimate the impact of fatigue on performance. The biological limits imposed by fatigue will impair the performance of even the most highly skilled and motivated individuals, and the effects of fatigue cannot be overcome by training or experience; one cannot train oneself to overcome the physiologic need for sleep. Nor can the impact of fatigue be negated by monetary or other incentives.[36] In any event, restricting sleep to less than six hours per day produces noticeable deteriorations in performance. Furthermore, remaining awake for prolonged periods can create difficulties in accomplishing even simple tasks. Caldwell revealed that just 17 hours of continuous wakefulness degrades aspects of performance to the same extent as a blood alcohol concentration (BAC) of 0.05 percent, the proscribed level of alcohol intoxication in many countries. After 24 hours awake, performance is reduced to the level of what would be observed with a BAC of 0.10 percent.[37] The performance of drowsy pilots becomes less consistent, especially during the night hours. Sleepy pilots often fail to respond appropriately to cockpit demands, and they are at serious risk for missing task-related details. Problem solving, reasoning, and control accuracy degrade. Overall the aviator's ability to pay attention to flight instruments and to manage radio communications, crew coordination, and navigational tasks is severely impaired.[38]

Physiological versus Subjective Sleepiness

It is usually difficult for most individuals to reliably estimate their own sleep or their waking alertness, especially if they are already sleepy. Overall there is a tendency for individuals to subjectively overestimate how long it takes to fall asleep and underestimate total sleep time; people fall asleep faster and sleep longer than they think. So when an individual experiences a bad night of sleep, it may not be as bad as it seemed. Nevertheless, the tendency is for individuals to subjectively rate themselves as more alert than is indicated by physiological measures. That is, most individuals are more likely to be sleepier than they report

or experience.[39] Data from an international study of flight crews illustrated that the highest subjective rating of alertness occurred at a time when physiologically the individual was falling asleep within six minutes (an indicator of severe sleepiness).[40]

Jet Lag

Jet lag can be defined as "the condition where the circadian clock is out of step with the environment."[41] The Ames Research Center asserts that crossing time zones produces an additional zeitgeber disruption regularly encountered by flight crews. The circadian clock resynchronizes only gradually to a new environmental time. Circadian rhythms in different bodily functions—such as hormone secretions, basal temperature, and blood pressure—adjust more or less quickly, depending on the tightness of their pairing to the clock and on their interactions with other physiological functions, with each adapting at its own rate. Thus, after a transmeridian flight, not only is the circadian clock out of step with the local zeitgebers but also different physiological functions are out of step with one another.[42] The typical guidance given is to provide a 24-hour recovery period for each time zone traveled. Frederick W. Rudge considers this to be a very conservative estimate. Instead, he believes that six hours of recovery per time zone is adequate.[43] E. L. Co and associates point out several factors that might affect an individual's ability to adapt to a new schedule:

- Individuals differ in their bodies' ability to adapt to schedule changes.
- The ability to adapt decreases with increasing age.
- The direction of the shift affects the ability to adapt. Westward travel is more natural to the circadian clock and is, therefore, easier than eastward travel.
- The more time zones crossed, the longer the adaptation takes.[44]

To help ensure that interruption in circadian rhythm will not affect performance on trips to distant places, the International Civil Aviation Organization (ICAO) has developed the following travel time formula.[45]

Rest period in tenths of days = travel time (hours) divided by 2 + time zones in excess of 4 + departure time coefficient (local time) + arrival time coefficient (local time). The departure time coefficient (DTC) and arrival time coefficient (ATC) are given in the following table.

Table 2

Departure and Arrival Time Coefficients

Period (hour)	DTC	ATC
0800–1159	0	4
1200–1759	1	2
1800–2159	3	0
2200–0059	4	1
0100–0800	3	3

Source: USAF, "Flight Surgeon Checklist," draft for residency for aerospace medicine course material, Brooks Air Force Base, Texas, March 2000, chap. 3.

In applying the formula, the following rules are observed by ICAO:

- The value obtained for rest periods, in tenths of days, is to be rounded to the nearest higher half-day. Rest stops that add up to less than a day before rounding will not be scheduled unless the journey involves an overnight flight on mission travel.
- "Travel time, in hours" means the number of hours of elapsed time required for the journey, rounded off to the nearest hour.
- "Time zones" are computed in increments of 15 degrees of longitude from Greenwich, England.
- "Departure time" and "arrival times" are local times.[46]

Notes

1. William J. "Bill" Clinton, *A National Security Strategy for a New Century* (Washington, D.C.: The White House, December 1999), 11.

2. Headquarters USAF/XOPE, EAF Implementation Division, *Aerospace Expeditionary Forces*, 1 October 1999.

3. F. Whitten Peters and Michael E. Ryan, *US Air Force Posture Statement 2000*, 30–31.

4. M. R. Rosekind et al., "From Laboratory to Flightdeck: Promoting Operational Alertness," *Royal Aeronautical Society*, 1997, 7.1–7.14.

5. M. R. Rosekind et al., "Fatigue in Operational Settings: Examples from the Aviation Environment," *Human Factors*, 1994, 36(2).

6. M. R. Rosekind et al., NASA Technical Memorandum 1999-208780, subject: Crew Factors in Flight Operations X: Alertness Management in Flight Operations, Moffett Field, Calif.: Ames Research Center, 1999.

7. Carol S. Ramsey and Suzanne E. McGlohn, "Zolpidem as a Fatigue Countermeasure," *Aviation, Space, and Environmental Medicine*, October 1997, 926–31.

8. Rosekind et al., "From Laboratory to Flightdeck."

9. John A. Caldwell, "Fatigue in the Aviation Environment: An Overview of the Causes and Effects As Well As Recommended Countermeasures," *Aviation, Space, and Environmental Medicine*, October 1997, 932–38.

10. M. R. Rosekind et al., "Fatigue in Operational Settings."

11. Caldwell.

12. Rosekind et al., NASA Technical Memorandum 1999-208780.

13. M. R. Rosekind et al., "Managing Fatigue in Operational Settings I: Physiological Considerations and Countermeasures," *Behavioral Medicine* 21, 1996, 157–65.

14. Ibid.

15. E. L. Co et al., "Fatigue Countermeasures: Alertness Management in Flight Operations, *Proceedings of the 11th Annual International Aircraft Cabin Safety Symposium*, Long Beach, Calif., 1994.

16. Rosekind et al., NASA Technical Memorandum 1999-208780.

17. Ibid.

18. Ibid.

19. Ibid.

20. Rosekind et al., "Fatigue in Operational Settings."

21. Rosekind et al., NASA Technical Memorandum 1999-208780.

22. Rosekind et al., "From Laboratory to Flightdeck."

23. Rosekind et al., NASA Technical Memorandum 1999-208780.

24. Rosekind et al., "From Laboratory to Flightdeck."

25. Ibid.

26. Ibid.

27. Rosekind et al., "Managing Fatigue in Operational Settings I."

28. Ibid.

29. Ibid.

30. Ibid.

31. Ibid.

32. Rosekind et al., "From Laboratory to Flightdeck."

33. USAF, "Flight Surgeon Checklist," draft for residency in aerospace medicine course material, Brooks Air Force Base, Tex., March 2000, 63–67.

34. John A. Caldwell, “Sleepiness in the Cockpit,” *Combat Edge,* August 1999.

35. Co et al.

36. Caldwell, “Fatigue in the Aviation Environment,” 932–38.

37. Caldwell, “Sleepiness in the Cockpit.”

38. Ibid.

39. Rosekind et al., NASA Technical Memorandum 1999-208780.

40. Rosekind et al., “From Laboratory to Flightdeck.”

41. Rosekind et al., NASA Technical Memorandum 1999-208780.

42. Ibid.

43. Frederick W. Rudge, “Operational Considerations,” *USAF Flight Surgeon’s Guide,* chap. 14.

44. Co et al.

45. “Flight Surgeon Checklist.”

46. Ibid.

PART III

Issue Analysis

Current Fatigue Countermeasures

Sleep, rest of nature, O sleep, most gentle of the divinities, peace of the soul, thou at whose presence of care disappears, who soothest hearts wearied with daily employments, and makest them strong again for labour!

—Ovid (43 B.C.–A.D. 18)

Ovid's insight into the importance of sleep helps stress the significance sleep has on performance. Consequently, alertness management strategies must be developed when the environment or setting precludes a good night's rest, such as those often found on AEF deployments. Alertness management strategies can "minimize the adverse effects of sleep loss and circadian disruption and promote optimal alertness and performance in operational settings."[1] The application of "strategic countermeasures" involves three components:

- Understanding the physiological principles related to sleep and circadian rhythms.
- Determining the specific alertness and performance requirements of a given operation.
- Taking deliberate actions to apply the physiological principles to meet the operational requirements.[2]

Alertness Management Strategies

Rosekind has differentiated alertness management strategies into two components: preventive strategies and operational strategies. Preventive strategies are used prior to duty or on layover to minimize the adverse effects of the underlying physiological factors (i.e., sleep loss and circadian disruption). These strategies include obtaining maximal quantity and quality of sleep prior to duty, scheduling sleep periods during layover, accounting for fatigue factors during trip scheduling, napping, maintaining good sleep habits, exercising, maintaining balanced nutrition, and others.[3] Preventive strategies address the major physiological causes of fatigue in flight operations, namely sleep loss and circadian rhythm disruption. Sleep loss, whatever its origins, has detrimental effects on performance. Circadian

rhythm disruption is an inevitable consequence of providing around-the-clock services and of transmeridian flight. P. H. Gander and associates propose that it can compromise cockpit performance in two ways. First, it may require crew members to be on duty during the part of the circadian cycle when their performance capacity and alertness are lowest. Second, it might displace crew members' sleep to parts of the circadian cycle when sleep quantity and quality, and therefore subsequent waking function, are compromised.[4]

Operational countermeasures are used in flight to maintain alertness and performance during operations. Generally, these strategies may be more short acting and serve to mask or conceal underlying physiological sleepiness. These countermeasures include physical activity, strategic caffeine use, and social interactions.[5] In general, operational countermeasures do not address the underlying physiological causes of fatigue. Instead, Rosekind points out that they are meant to enhance alertness and performance temporarily so that operational safety and efficiency are maintained.[6]

Both types of alertness management strategies used to counter the effects of fatigue can be organized into pharmaceutical and nonpharmaceutical means. Some strategies, such as the consumption of caffeine, can be categorized in both types depending upon the time of administration.

Pharmaceutical

To enhance performance in a smaller and aging military, the National Research Council and others have suggested that "greater consideration be given to the use of pharmaceuticals during extended flight missions and sustained operations."[7] K. M. Belland and C. Bissell found that during Operations Desert Shield and Desert Storm the USAF used performance maintenance medications (amphetamines and temazepam), and these medications showed no adverse effects and helped to maintain performance levels during flight operations.[8] Additionally, they noted that the Air Force stimulant and sedative protocols emphasized prudent planning and recognition of human performance

parameters, as well as the necessity for flight surgeons to closely monitor the physiologic and psychologic status of aircrew personnel.[9] When operational constraints prevent the use of behavioral strategies for the alleviation of aircrew fatigue, pharmacological countermeasures may be the only option for maintaining aviator performance. Air Force Instruction (AFI) 48-123, *Medical Examination and Medical Standards*, 1 January 2000, is the primary source for the rules regarding medications that can be waivered for flying duties. As a general rule, the use of medications will usually require approval by the appropriate waiver authority. Waiver action for any medication cannot be considered until "control of the condition has been demonstrated and the absence of side effects has been determined and documented."[10] Table 3 gives a summary of three typical medications and their associated effects.

Restoril. Temazepam (Restoril) was, until recently, the only hypnotic approved by the USAF for aircrew use. A 12-hour grounding period following administration is required due to its long elimination half-life of 8.4 +/- 0.6 hours. As the number of continuous hours awake contributes significantly to a decrease in alertness, if Restoril is used for pre-mission or in-flight napping, theoretically it could worsen fatigue toward the end of a mission. Carol S. Ramsey and Suzanne E. McGlohn reported that the drug causes persistent drowsiness in some individuals.[11]

Dexedrine. Recent studies indicate that dextroamphetamine (Dexedrine) has been effective in aviation contexts. EF-111A Raven jet crews administered five milligrams (mg) of Dexedrine during an Air Force strike on Libya in April 1986 experienced positive effects in terms of overcoming the fatigue of the mission itself and the sleep deprivation which occurred during mission preparations.[12] Air Force pilots effectively used dextroamphetamine during Operation Desert Storm to maintain acceptable performance during continuous and sustained missions. The medication was found to be beneficial in terms of overcoming fatigue without producing unwanted side effects.[13] In one study the beneficial effects of Dexedrine were particularly apparent from early morning until noon after a night of sleep loss, although drug-related performance enhancements were seen later as well.[14] A major finding was that

Table 3

Comparative Profiles of Zolpidem, Triazolam, and Temazepam

	Zolpidem (Ambien)	*Triazolam (Halcion)*	*Temazepam (Restoril)*
Usual dose	10 mg	0.25 mg	15 mg
Peak effect	1.6 h	2 h	1.5 h
Avg. elimination half life	2.6 h	3.1 h	8.4 h
Active metabolites	No	No	No
Impact on sleep architecture	Slight absolute increase in Stage 4 (NREM)	Increased Stage 2, Reduced Stage 3–4, Reduced REM	Increased Stage 2, Reduced Stage 3–4, Reduced REM
Rebound insomnia	No	Yes	+/–
Anterograde amnesia	No	Yes	Yes
Persisting AM drowsiness (hangover)	No	+/–	Yes (Drug accumulation after 3 doses)
Tachyphylaxis	No	High (>7–10 d)	Moderate
Acute withdrawal effects	No	Yes (Similar to alcohol and phenobarbital)	Yes (Similar to alcohol and phenobarbital)
Drug interactions	Phenothiazines Haliperidol SSRI's (?)	Alcohol Oral Contraceptives Ciprofloxin Erythromicin INH Omeprazol Cimetidine	Alcohol Oral Contraceptives Ciprofloxin Erythromicin INH Omeprazol Cimetidine
Use in Pregnancy	Category B (Maturation defects in animal studies at high doses	Category X (Teratogenic in first trimester)	Category X (Teratogenic in first trimester)

Source: Carol S. Ramsey and Suzanne E. McGlohn, "Zolpidem As a Fatigue Countermeasure," *Aviation, Space, and Environmental Medicine,* October 1997, 927.

Dexedrine was valuable when given prophylactically to pilots for the prevention of performance decrements associated with sleep deprivation.[15]

Zolpidem. Ramsey and McGlohn confirmed that Zolpidem appears to be a preferable agent to benzodiazepines for use in aviators because it is relatively free from debilitating side effects and does not cause tolerance or promote drug dependence. It preserves normal sleep architecture and shows promise in providing restorative sleep in situations not normally conducive to sleep: troop transport, napping during extended missions, permission or preshift napping, and crew rest during circadian "forbidden periods."[16] Acute and chronically fatigued individuals may gain a strategic advantage if they are able to obtain pharmaceutically aided restorative sleep.

Caffeine. Caffeine—present in coffee, cola drinks, and chocolate—is considered to be habituating at a level of 10 mg/kilograms per day. Since one eight-ounce cup of coffee contains approximately 100 mg of caffeine, somewhere between six to 10 cups of coffee per day would produce this level.[17] Caffeine is also known to sustain overnight performance and improve performance during the day and has been used in air operations. However, it may disturb recovery sleep, and there is some evidence that it may impair performance at higher doses. Caffeine stimulates the central nervous system (CNS), generally effective in 15 to 45 minutes after ingestion. It usually remains active for three to five hours, although the effects can continue for up to 10 hours in sensitive individuals.[18] In addition, Anthony N. Nicholson and Claire Turner advise that caffeine may increase feelings of nervousness and tension; and there may be considerable individual differences in the effects of the drug, often depending on levels of dietary intake.[19] Regardless of the level of habitual consumption, caffeine before sleep leads to lighter sleep with more awakenings and reduced total sleep time. Some conservative recommendations suggest no caffeine consumption as much as six hours before bedtime.[20] Although caffeine has been cleared of an association with initial myocardial infarcts, Rudge stresses that its stimulant effects on the CNS are of concern. During a temporary withdrawal from caffeine, as might occur during a deployment, the resulting

restlessness and disturbed sleep could add unnecessary burdens to an already fatigued crew. Caffeine is a known diuretic, and it can sensitize the heart to the development of irregular heartbeats. Neither of these side effects is desirable, particularly in pilots of high-performance aircraft.[21] Caldwell adds that caffeine should not be consumed throughout the duty period, but rather when drowsiness becomes apparent.[22]

Nicotine. Nicotine has much the same effects as caffeine on nocturnal sleep and subsequent daytime sleepiness and performance. Like caffeine, nicotine consumption (either tobacco smoking or patch) should not occur within several hours prior to the desired onset of sleep.[23]

Nonpharmaceutical

Four nonpharmaceuticals that may affect sleep or alertness are noted in this research paper. There is considerable interest in minimizing sleep loss, crew rest guidelines, environment, and exercise and diet—all of which may affect the circadian cycle.

Minimizing Sleep Loss. There is no substitute for a good night of sleep. Caldwell maintains that the most effective strategy for minimizing fatigue on the job is for all crew members to obtain adequate sleep prior to the duty period.[24] On working days, it is desirable to get at least as many hours of sleep as a normal night of sleep on a nonworking day. If the work schedule requires wakefulness during the part of the circadian cycle normally programmed for sleep, it may not be possible to obtain the usual daily quota of sleep in a single episode.[25]

At certain times in the circadian cycle, it is easy to fall asleep; and at other times, the brain is programmed to be awake. For this reason, it is important to take advantage of feeling sleepy by sleeping if circumstances permit. Conversely, it is impossible to force sleep! Trying unsuccessfully for 15 to 30 minutes to fall asleep is a signal to abandon the effort for the time being and to get out of bed.[26]

Crew Rest Guidelines. Adequate crew rest is normally seven to eight hours of uninterrupted sleep, which utilizes the sleep hygiene principles. It is important to distinguish between the officially designated crew rest times and the

actual amount of sleep the crew gets.[27] AFI 11-202V31, *General Flight Rules*, discusses crew rest and flight duty limitations. Air Force aircrews require at least eight hours of continuous, uninterrupted rest during the 12 hours immediately prior to the beginning of the flight duty period.[28] If an aircrew member remains after flying to perform official duties, the crew rest period begins after termination of these duties. The flight duty period is defined as "a period that starts when an aircrew reports for a mission, briefing, or other official duty and ends when engines are shut down at the end of a mission, mission leg, or a series of missions."[29] The minimum crew rest period is 12 hours; and when only one pilot is aboard, the maximum flight duty period is also 12 hours.[30] The duty period drops to 10 hours at night for single-seat aircraft.[31]

Environment. Physical aspects of the environment can also affect sleep. A dark, quiet room is preferable. Eyeshades are a simple and portable solution to the problem of light. Unless it is necessary to be available to be awakened, earplugs can also be helpful to reduce noise. Sudden sounds can disturb sleep, so providing continuous background "white" noise can be helpful. One suggestion from flight crews is to set the radio between two stations for this purpose. In general, sleep quality is better if the environment is cooler rather than hotter. A comfortable sleep surface is also important.[32] Aviators should make every effort to make the environment as comfortable as possible. Moreover, Caldwell recommends carrying a family picture, one's own pillow, or some other small, familiar object on deployment to make the new environment more familiar and relaxing.[33]

Exercise and Diet. Exercise has been demonstrated to facilitate circadian adaptation in animals, though there has not yet been a demonstration in humans.[34] In laboratory studies with rodents, an exercise bout in the morning advances the circadian clock, whereas an exercise bout in the evening delays it.[35] The discomfort associated with being hungry, or with having eaten too much, may interfere with falling asleep. If one is hungry or thirsty at bedtime, a light snack or a small drink is preferable.[36] There is also considerable interest in possible dietary constituents that might be able to promote sleep or alertness,

or to reset the circadian clock. It has been suggested that foods rich in carbohydrates (e.g., legumes, pastas, potatoes) may induce sleep by elevating serotonin levels. Conversely, foods high in protein (e.g., meats, dairy products, eggs) and certain amino acids are proposed to promote wakefulness by enhancing catecholamine activity.[37]

Depending upon where the AEF is deployed, alcohol consumption might be an issue of concern. Alcohol is reputedly the most commonly used sleep aid in the United States.[38] It can promote relaxation and thereby help a person to fall asleep; but it also produces easily disrupted, lighter sleep. It suppresses REM sleep in the first half of the night, leading to REM rebound and withdrawal effects in the second half.[39] It is advisable to finish drinking sufficiently early to allow the blood alcohol level to return to zero before sleep. Even then, "sympathetic arousal follows the decline of blood alcohol levels, and may persist for two to three hours after the blood alcohol concentration returns to zero."[40]

Future Fatigue Countermeasures

There is considerable interest in chronobiotics—that is, "drugs, hormones (e.g., melatonin) and other treatments (e.g., bright light) that are potentially capable of accelerating the adaptation of the circadian clock to a new duty/rest schedule or time zone."[41] However, there are a number of practical considerations that Gander and associates expose that—for the moment—limit the potential usefulness of chronobiotics for flight crews. The time in the cycle at which a chronobiotic is administered is critical, and opposite effects can be achieved by displacing the dose by several hours. Chronobiotics used in everyday life must act against a background of all the other environmental time cues to which an individual is exposed. While there are ways of minimizing these extraneous cues (e.g., wearing dark glasses to reduce the effects of sunlight or minimizing contact with the local social environment), crew member acceptance of and compliance with fatigue countermeasures that require such discipline is a real issue. Finally, none of the chronobiotics currently being considered

has been shown to be effective in field tests in any aviation environment.[42]

Pharmaceutical

The following drugs—melatonin, tyrosine, and pemoline—deserve a word of caution concerning their availability. Many medications available by prescription in the United States can be obtained over the counter, without prescription, in many overseas locations and in some cases at your local drug store. Presently, none of these medications has been approved for use by aircrews. The information provided here is intended only to give a basic understanding of their effects.

Melatonin. Melatonin is a hormone produced in the pineal gland. Bright light suppresses melatonin secretion, while darkness causes the pineal gland to release melatonin, causing drowsiness. Unfortunately, as Susan E. Northrup points out, when more than three time zones are crossed, the cycle continues with the body clock—which is the primary regulator of melatonin, not the local time zone.[43] However, the proper use of melatonin tablets may not only resolve sleeping problems (sedative effects) after a long flight but can also actually speed up the resynchronization of the body clock to a new time zone.[44]

Tyrosine. Tyrosine is a large, neutral amino acid found in dietary protein. It has recently been considered as a potential countermeasure to stress in humans. David F. Neri observed decreases in psychomotor performance, vigilance, and auditory attention, and increases in reaction times and response lapses in sleep-deprivation studies. However, with the administration of tyrosine, significantly smaller performance lapses were observed. Consequently, he concluded that this relatively benign substance might prove useful in countering performance decrements during episodes of sustained, stressful work coupled with sleep loss.[45]

Pemoline. Pemoline—a dopamimetic drug that acts as a stimulant—has the potential to improve alertness and performance in well-rested and sleep-deprived subjects, and its stimulant activity does not appear to be dependent on the time of day or the duration of prior wakeful-

ness. It is relatively free of adverse effects on recovery sleep and of dependence.[46]

Nonpharmaceutical

The following nonpharmaceutical strategies are briefly discussed to provide a basic understanding of their circadian adaptation.

Bright Lights. Bright light has been shown in laboratory studies to facilitate rapid circadian adaptation. Two to three hours of bright light (i.e., 2,500–10,000 lux) administered at the appropriate phase of the temperature cycle for three successive days may facilitate an eight- to 12-hour shift of the circadian clock. Separate from its effects on the circadian clock, bright light may also have an independent alerting effect.[47] As stated earlier, in addition to its capacity to reset the circadian clock, light of this intensity suppresses secretion of the pineal hormone, melatonin, and appears to have an alerting effect—although the mechanism of this is not clear.[48]

Strategic Naps. Generally, studies have demonstrated that naps maintain performance compared to baseline conditions or improve performance compared to conditions of prolonged wakefulness without naps.[49] A nap reduces the length of continuous wakefulness before a work period and can be especially beneficial before a period of night work, when the challenge of working through the circadian low point is also a factor.[50] Caldwell discusses five factors that affect the advantage of napping.

- The feasibility of creating a suitable nap environment which is close to the workplace.
- The appropriate placement of the nap in the 24-hour period—during the nighttime period that normally coincides with sleep.
- The appropriate placement of the nap relative to the sleep deprivation period—prior to anticipated sleep deprivation.
- The length of time which should be allowed between the end of the nap and the beginning of the next work task.
- The appropriate nap duration so as to maintain or recover performance during periods of continuous wakefulness.[51]

Current perspectives on napping suggest that 30-minute naps (short nap) or naps of about three to four hours (long nap) are much more restorative than naps for any other lengths of time. These two strategies, the short nap and the long nap, are designed to miss the singly slow wave sleep period associated with stages three and four sleep.[52] The napping strategies are designed to provide an adequate rest while dramatically shortening the time it takes for someone who was asleep to reach useful consciousness. Sleep inertia is shorter after REM, perhaps as short as a minute or two.[53]

Rosekind suggests that naps can be a useful strategy in both a preventive and an operational manner. As a preventive strategy, naps can be used as a protective measure to maintain alertness and performance during a subsequent period of prolonged wakefulness. A nap can also be used to reduce the hours of continuous wakefulness before a shift or duty period and the total hours awake at the end of the subsequent work period. As an operational strategy, naps can be used to interrupt sustained periods of wakefulness during a continuous operation to maintain the level of subsequent performance and alertness.[54]

In addition to the two strategies, Rosekind identified six major domains that should be addressed in an integrated program to manage fatigue in operational settings: education and training, hours of service, scheduling practices, countermeasures, design and technology, and research.[55]

Education and Training. Development and implementation of education and training materials will establish the knowledge base for all other activities. Rosekind suggests that the materials should provide information on the physiological mechanisms that underlie fatigue, address some of the misconceptions about fatigue, and make specific recommendations for countermeasures.[56] In 1994 NASA Ames Research Center's Fatigue Countermeasures Program, in collaboration with the Federal Aviation Administration (FAA), developed an education and training module titled Alertness Management in Flight Operations. The module is distributed to the aviation industry through two-day workshops held at the NASA Ames Research Center.[57]

Hours of Service. The number of hours that individuals work can be regulated. Rosekind also recommends that

the specific guidelines include approaches that maintain operational flexibility. Whenever possible, these guidelines should rely on scientific data balanced with the operational demands of the units.[58]

Scheduling Practices. Whenever possible, scheduling approaches should attempt to incorporate scientific research on fatigue. Some European approaches involve rotating shift schedules over a matter of days (i.e., fast rotation) compared to the usual US practice of rotating shift schedules over weeks (i.e., slow rotation). The European approach is based on data suggesting that shift workers do not adjust to a rotated schedule and therefore should spend minimal time rotating their schedule.[59] Personnel who transition to a new time zone or work schedule for only brief periods should not attempt to readjust their circadian rhythms but should try to remain on their original meal and activity or rest schedules as much as possible.[60]

Countermeasures. There are a wide range of strategies available that include personal, unit, and regulatory means. The specific strategies are discussed in other sections of this paper. However, Rosekind emphasizes that individuals have a personal responsibility to incorporate these strategies into their own lives.[61]

Design and Technology. Although technology in our military continues to evolve with great speed, the human operators in the center of the advancing technology have not evolved at all in their need for sleep and circadian stability. Potential technological areas include scheduling algorithms and alertness monitoring/management systems. One example of using technology to address fatigue issues is in an alertness warning system that Boeing has included as an option on its 747 and 767 aircraft. This system alerts the flight crew when no interaction with the flight-deck computers has occurred during a certain programmable time period.[62]

Research. Although a tremendous amount of scientific information is now available on fatigue, sleep, and circadian physiology, much is still unknown. This is especially true in the application of this scientific knowledge to operational issues. More research will be required to identify and generate data that address specific operational issues, such as regulatory, scheduling, and countermeasure questions.[63]

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PART IV

Conclusions and Recommendations

Conclusions and Recommendations

My mind clicks on and off . . . I try letting one eyelid close at a time while I prop the other open with my will. But the effort's too much. Sleep is winning. My whole body argues dully that nothing, nothing life can attain, is quite so desirable as sleep. My mind is losing resolution and control.

—Charles A. Lindbergh
Spirit of St. Louis

Global demand for AEF presence continues to outpace our military's resources. Therefore, the safety and operational issues of managing fatigue will remain, and potentially worsen, with increasing demand. Attempts to deny, minimize, or distract fatigue as a dangerous operational issue will only delay effective action while the associated risk continues or increases. Other transportation modes have fully acknowledged fatigue as a safety issue that deserves attention and creative management solutions.[1] Clearly no single "cure" or magic bullet can eliminate fatigue from 24-hour operational settings. Operational demands, human physiology, and individual differences are too complex for a simple mechanistic approach. By examining each component of the system, however, one can identify areas in which to incorporate current scientific knowledge regarding fatigue. It will be critical to develop and use approaches to maintain operational flexibility to meet 24-hour global requirements. The challenge is to incorporate fatigue-related knowledge while balancing the need to meet operational demands. As long as around-the-clock operations are required to maintain military commitments, the effects of sleep loss and circadian disruption must be considerations in any operational setting. How these factors affect the physiological and performance capabilities of the human operator will be critical to job safety, performance, and productivity.[2]

Kelly J. Neville and associates advise that adequate training about the impact of fatigue and sleep loss on safety and effectiveness—and the fact that fatigue cannot be overcome through willpower or motivation—should be provided to every aircrew member.[3] This training—combined with knowledge of effective strategies for avoiding fatigue through proper sleep management and attention to circa-

dian factors—should enable aviators and their commanders to maintain safe and effective air operations even in difficult circumstances. Literature suggests schedules could be adjusted to be more compatible with circadian rhythms and special circumstances. Layover periods for transport aircrews must coincide with periods of peak sleepiness (early morning and midafternoon), and peak workload should coincide with periods of maximal alertness.[4]

The predominant cause of chronic sleep difficulties in otherwise healthy individuals is poor sleep hygiene. Pilots can substantially improve daytime alertness by adhering to a proper sleep routine each night. This sequence includes going to bed every night at a consistent time, avoiding caffeine and alcohol prior to bedtime, establishing a healthy exercise routine, and avoiding mental associations that are inconsistent with initiating and maintaining sleep.[5] The *USAF Flight Surgeon's Guide* offers several techniques for improving sleep hygiene.[6]

- Get rid of sleep debt (allow eight to 10 hours of sleep for a few days before a long mission or period of nighttime vigilance).
- Avoid excessive alcohol (a blood alcohol of more than the legal limit before you go to bed can cause profound insomnia; drink water before bed but not so much that you will have to get up later to urinate).
- Avoid large meals before you go to bed (leave about six hours before sleep for digestion).
- Sleep as comfortably as possible in a quiet and as dark as possible environment.
- Don't prop the pillows up too high if you sleep on your back as this can block the airways when REM atonia, the lack of muscular tension, occurs.
- Personal hygiene helps sleep. Brush your teeth and shower and dress comfortably for sleep and after awakening.
- Avoid caffeinated beverages three to four hours before bed. You might not think that it hurts your sleep, but it will cause a restless sleep.
- Use short nap (<30 minutes) or long nap (three to four hours) strategies.

- Avoid strenuous exercise about three to four hours before bed.
- Get to bed at the same time each night as closely as possible.
- Consistency in sleep habits (time, procedures) is very important to maintaining biological cyclicity.
- Try deep breathing and muscle relaxation techniques to help with stress reduction and sleep onset.

Rosekind and associates identify four core operational issues where scientific data are available to support policies.[7] The first issue involves the fact that the "critical foundation for optimal performance and alertness during operations is established by an appropriate quantity and quality of sleep prior to duty."[8] Are there individual differences and can individuals in certain circumstances operate on less than eight hours of sleep? The answer to both questions is yes. However, policies should address average requirements and not rely on the "extra" effort required to cope with sleep loss in nominal operations. As previously addressed, reported and habitual sleep amounts are not necessarily indicators of an individual's actual sleep need. Therefore, one core operational issue is establishing a minimum rest that provides for an eight-hour sleep opportunity every 24 hours.[9]

The second issue involves the length of continuous wakefulness. Complementary to an appropriate minimum rest is the length of continuous wakefulness, traditionally identified as the duty period. Data from NTSB aircraft accident investigations indicate an increased risk exists beyond the 12-hour duty period. Analysis of a national occupational-injury database showed a constant accident or injury rate through nine consecutive hours of work and then a progressive increase to three times the rate at 16 hours of work.[10]

The third issue addresses circadian factors or time of day. This powerful modulator of human performance and alertness affects three aviation operations: night flying, time zone changes, and day and night duty shifts. The circadian trough (0300 to 0500) and night in general (0000 to 0600) are associated with significant degradation in performance and alertness and increases in errors and

accidents.[11] Therefore, the time of day that an operation occurs should be a consideration. The stability of performance during a 14-hour daytime duty period is not the same as during a 14-hour nighttime duty period.

The fourth issue includes minimizing the cumulative effects of fatigue. It is important to maintain an optimal sleep opportunity every 24 hours and also to address the potential for cumulative effects. Therefore, appropriate recovery time should be allowed per week (days or rolling hours).[12] When the author was deployed in support of an operation that flew seven days a week, the commander made sure that supervisors gave their personnel a day off every two weeks. While the intent can be commended, it still falls short of nullifying the cumulative effects of fatigue.

While flight, duty, and rest policies are one necessary component of addressing fatigue in aviation operations, they are not sufficient. The operational environment is complex and diverse and thus precludes a single and simple solution to managing fatigue. An integrated, multicomponent approach to managing fatigue in aviation operations offers more comprehensive improvements and potential flexibility.

Literature strongly suggests that the following factors be considered before implementing naps or other alertness management strategies in real-world operational settings:

- *An identifiable benefit:* An alertness management strategy should provide a clear and identifiable benefit to the aviator and the operational environment (e.g., increased safety margin). It should minimize some adverse consequences or promote a particular positive outcome.
- *Opportunity:* An appropriate opportunity for implementation should be identified. In some operational circumstances it may not be appropriate to consider a certain strategy (e.g., napping during a flight in a single-seat fighter).
- *Unit climate/culture:* Some strategies may be explicitly or implicitly supported, while others are actively suppressed.

- *Operational demands:* The specific work demands and circumstances of a particular work environment may exclude some potential strategies.
- *Safeguards:* Alertness management strategies are intended to promote safety and productivity. Specific safeguards should be employed to ensure that strategies do not negatively affect the safety margin.[13]

In the preceding sections the latest scientific data were presented to aid commanders and aviators in combating the fatigue anticipated and associated with AEF deployments, as well as while employing under stressful, unfamiliar circumstances. However, there is more information that needs to be addressed. The author, having been operational for more than 12 years, is fully aware of the "real world" issues concerning fatigue. The reality of the situation is that fatigue and its negative consequences are, in general, downplayed at best and completely ignored in extreme circumstances. First, when a squadron deploys, the flight surgeon typically is not given adequate time to address all of the topics and countermeasures covered in this research. The doctors are usually limited in the amount of time they are given to address a wide variety of deployment concerns, with fatigue and circadian factors being only one of them. Consequently, many pilots are uninformed about the potential dangers linked with fatigue. Second, there seems to be a stigma associated with fatigue, especially true in the fighter community, whereby aviators are expected to "gut it out" if they feel tired. Many flyers treat fatigue as a joke or as a sign of hard work rather than as a signal that their bodies are in need of rest. Third, when medications are given to keep pilots awake on long deployments, some aviators misuse the drugs by saving them up for when they land instead of using them during flight at the onset of fatigue symptoms, as directed.

The challenge for commanders is to shatter the stereotypes of fatigue and emphasize the importance of proper sleep habits and appropriate countermeasures. Eliminating the images among aviators that fatigue is a sign of weakness, laziness, or lack of motivation will be one of the commander's most difficult tasks. It all begins, however, with allotting the flight surgeon enough time to address

the problems of sleep debt and its effects upon performance and safety. Giving the doctors more equitable time with other support agencies such as weather, intelligence, and mission planners creates a mindset among the flyers that this topic is important and demands attention. Furthermore, a commander who personally stresses fatigue-related concerns to his or her troops sends a message that it is all right to get tired and that rest is an option. Fourth, commanders must be aware that change can be a slow process, and that they must remain proactive in identifying those aviators who refuse to back down. If they believe that the flyer is fatigued, they must act responsibly by removing them from the flying schedule or emphasize to subordinate supervisors to do the same. Relying upon individuals to make the right decision when they are tired can be a formula for disaster.

There are many ways to combat the effects of fatigue and circadian disruption. Many of these strategies are presented in this paper. However, it is up to commanders to be responsible to this insidiously dangerous risk and to incorporate them into their decision-making process. In order to assist commanders with dealing with the impact fatigue might have on deploying units, the author recommends that the USAF Battlelab use the information from this research to pursue the development of a commander's handbook. This guide should provide commanders with useful data concerning alertness management strategies as well as fatigue countermeasures. The handbook will allow commanders to place increased emphasis on fatigue's impact on performance and safety with the aviators on AEF deployments. Many—if not all—pitfalls of fatigue can be prevented or managed more effectively.

Notes

1. M. R. Rosekind et al., "From Laboratory to Flightdeck: Promoting Operational Alertness," *Royal Aeronautical Society*, 1997, 7.1–7.14.

2. M. R. Rosekind et al., "Fatigue in Operational Settings: Examples from the Aviation Environment," *Human Factors*, 1994, 36(2).

3. Kelly J. Neville et al., "Subjective Fatigue of C-141 Aircrews during Operation Desert Storm," *Human Factors 36(2)*, 1994, 339–49.

4. Ibid.

5. John A. Caldwell, "Fatigue in the Aviation Environment: An Overview of the Causes and Effects As Well As Recommended Countermeasures," *Aviation, Space, and Environmental Medicine,* October 1997, 932–38.

6. V. A. Convertino et al., "Health, Fitness, and Nutrition," *USAF Flight Surgeon's Guide,* chap. 14.

7. Rosekind et al., "From Laboratory to Flightdeck."

8. Ibid.

9. Ibid.

10. Ibid.

11. Ibid.

12. Ibid.

13. M. R. Rosekind et al., "Alertness Management: Strategic Naps in Operational Settings," *Journal of the Sleep Research Society* 4, n.d., 62–66.

PART V

Glossary, Definitions, and Bibliography

Glossary

AEF	Aerospace Expeditionary Force(s)
AEG	Aerospace Expeditionary Group
AES	Aerospace Expeditionary Squadron
AFI	Air Force Instruction
ASRS	Aviation Safety Reporting System
ATC	arrival time coefficient
BAC	blood alcohol concentration
CINC	commander in chief
CNS	central nervous system
EAF	Expeditionary Aerospace Force
FAA	Federal Aviation Administration
ICAO	International Civilian Aviation Organization
NASA	National Aeronautics and Space Administration
NREM	nonrapid eye movement
NTSB	National Transportation Safety Board
REM	rapid eye movement
USAF	United States Air Force

Definitions

Aerospace Expeditionary Force. A cross section of capabilities that can be tailored to meet theater CINC needs (http://www.af.mil/eaf/faq).

Air Force Instruction (AFI). A regulation governing a particular aspect of duty-related functions.

Aircrew. The full complement of officers and enlisted members required to operate an aircraft and to complete an assigned mission (AFI 11-202, *General Flight Rules,* vol. 3, June 1998, 42–45).

Class A mishap. The most destructive class of mishaps in terms of loss of life or damage to aircraft. It is defined by a total mishap cost of $1,000,000 or more, a fatality or permanent total disability, or destruction of an Air Force aircraft (AFI 91-204, *Safety Investigations and Reports,* 29 November 1999, 45).

Crew rest period. The crew rest period is the nonduty period before the flight duty period begins (AFI 11-202, vol. 3, 42–45).

Expeditionary Aerospace Force. The way the US Air Force will organize, train and equip to create a mindset and cultural stat that embraces the unique characteristics of aerospace power—range, speed, flexibility, precision—in all that we say and do. It is made up of AEFs, AEGs, and AESs (http://www.af.mil/eaf/faq).

Flight duty period. A period that starts when an aircrew reports for a mission, briefing, or other official duty and ends when engines are shut down at the end of a mission, mission leg, or a series of missions (AFI 11-202, vol. 3).

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